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INTRODUCTION

As noted in the title, this paper is to be directed primarily at the technologies for using wood residues in developing countries. The subject cannot be well addressed without first looking at the type of residues and the quantities available. While this paper generally addresses the problem of residue use in all developing countries, the greatest impact is going to be in the tropical countries, for that is where the greatest volume of wood use is occurring. Although specific figures cannot be cited for the amount of residue in each country (Liversidge 1973), estimates can be made for regions, and developing and developed country status based on figures from FAO (1989) (Table 1). A definitive text has just been released on this subject (Hakkila 1989), hopefully we will add new information not in his text.

Basically there are two broad categories of residues: (1) logging, (2) milling.

Logging Residues

Logging residues are created, for the most part, in the forest. These consist of unused materials from harvested trees, and from trees damaged or killed during the logging operation. It is generally conceded that about half the above-ground biomass of each harvested tree is left in the forest, although King and Smith (1974,1975) state that in England the figure is 40%. Logging residues are largely tops, including unused stem and branches; rotten, crooked or other logs, or portions thereof deemed unusable; and stumps, but may include roots. Hardwood residues from logging are usually considerably more than those from softwoods, and offer more opportunities. In some cases the residues may be as much as two thirds of the volume of the standing tree.

Craft (1976) in a study of Appalachian hardwoods in the U.S. found, that on a weight basis, 1.8 times as much useable material was removed as residue as was harvested as primary logs. A sizeable portion of the sawable residue was in small diameter, short-length logs in the tops of felled trees, and in residual trees. The average size of the sawable material was 18 cm in diameter and 1.8 m in length. Of the tops and residual trees, about 37% was in chippable material, and about 63% in sawable residue.

Martin (1976) provides estimates of the residue left in hardwood logging based on stand age, stand basal area, and type of logging. Generally he shows that older, and denser stands, and stands cut taking all sawlogs, but only sawlogs, produced the largest amount of residue.

Milling Residues

Milling residues are the unused parts of logs milled for lumber or veneer in primary and secondary processing operations. While most mill operators will claim less than 50% residues (that is, more than 50% recovery in product) the true figures are often far less (Lunstrum 1982). In 1969 figures from the western U.S. showed an average softwood residue percentage of 56.4, varying from 52 to 61 percent (Gedney and Henley 1971). By 1979, with major changes in sawmill efficiency, the softwood residues from study mills were reduced to about 49% (Anon. 1981, Lunstrum 1982). For hardwoods, Clark (1976) showed the following percentages of residue and lumber for yellow-poplar (*Liriodendron tulipifera*) in Eastern U.S.; 18% chippable, 15% bark, 13% sawdust, and 54% lumber. However, this was a laboratory study conducted under controlled conditions, and only partially reflects the expected results in an operating sawmill. In Australia, Ironside (1973) estimates hardwood residue volume at 61% of gross volume. The residues were 21% bark, 28% net defect, 16% sawdust, and 35% slabs and edgings. Many tropical mills will recover as little as 30% product from the log input, leaving 70% residue (Iyamabo Ofr 1990). Mamit, Wee, and Lai (1985) in a survey of 43 mills in Sarawak, Malaysia during 1983 showed a residue accumulation of 421,649 m^3 and a product to waste ratio of 0.75. They further commented that the disposal of the residues was leading to environmental decline.

Residue Reduction

While we need to discuss the technologies that can be applied for use of residues, the best thing that can be done is to reduce the amount of residue being generated. The reduction of residues relates directly to the number of trees needed for a quantity of product. Higher efficiency means fewer trees needing to be harvested (Anon. 1981, Lunstrum 1982), a key factor in the perpetuation of the world's forests.

Briefly let us look at some of the activities that can be used to reduce waste in logging and milling. In an effort to reduce logging and mill waste and to improve efficiency, the U.S. Forest Products Laboratory has developed a plan called IMPROVE, which is a series of eight programs for logging and mill improvement. The series includes guides to improvement of log processing, lumber manufacture, veneer manufacture, lumber and veneer drying, plywood manufacture, dry end practices, and dry storage (Anon. ND)

Logging inefficiencies are the source of most residues in the forest. Some of these are:

* High stumps
  Reduce stump height or remove stumps for products
* Merchantable limits too high (top diameter limits too large)
  Reduce top diameter limits and use whole tree logging to accumulate residues for better use
* Felling damage to the trees cut and to other trees
  Use more caution in felling operations, including training of cutters.
* Skidding damage to the log or tree being skidded and to other trees
  Train skidder operators to avoid residual tree damage. Lay out cutting operations so damage will be minimized.

* Improper bucking of logs
  Train buckers to cut more accurately, and evaluate logs for best yield.
* Unused lesser known species
  Evaluate lesser known species for applicable use and develop markets for these species.
* Diameter breast height limits too high for some species
  Some species never grow to large diameters, maturing at diameters under the legal limit for harvest. These species should be identified and separate diameter-cut limits be applied.

Milling inefficiencies also generate much residue. Some of these are

for sawing:
* Improper log storage
  Keep logs in ponds or under spray if not immediately used.
* Improper log bucking
  (Lunstrum 1982) (Sim 1980)
  Train buckers to accurately buck for length and quality.
* Excessive saw kerf
  (a) use band saws. (b) maintain the mill and saws better.
* Excessive debarking
  Maintain control on debarker to remove just bark and not wood
* Excessive slabs and edgings
  (Lunstrum 1982, Arima and others 1985)
  Train sawyer to recover as much product as possible, use shadow or laser cutting guides.
* Improper mill design
  Have consultant advise.
* Improper mill maintenance
  Establish regular and rigorous maintenance program for all parts of mill. Have printed checklist for each machine.
* Improper drying of lumber
  Train drying people in proper methods and in quality control.

for veneering:
* Improper log storage
  Keep logs in ponds or under spray if not immediately used.
* Improper log bucking
  Train buckers to accurately buck for length and quality.
* Improper log centering
  Obtain plexiglass, light, or laser centering device.
* Improper lathe or slicer setup
  Train operator to properly set up machines, provide checklist for setup procedure.
* Improper veneer clipping
  Establish quality control guidelines and train operators to follow them.
* Improper veneer drying
  Establish quality control guidelines and train operators to follow them.
* Improper mill maintenance
  Establish regular and rigorous maintenance program for all parts of mill. Have printed checklist for each machine.

Unavoidable Residues

There are unavoidable residues generated in both the forest and mill. These are the residues that must be considered even after improving the efficiency of logging and milling.

In the forest these residues consist of tops and bark. Some would also suggest using stumps and roots, but there are arguments against such use, especially in the poor soils of many tropical locations, where depletion of nutrients is critical.

In the mill there will always be residues from processing. These include bark, sawdust, slabs and edgings, planer shavings, veneer roundup waste, clipping waste, sanding dust, and veneer cores.

Economics

One further discussion that is necessary, before getting to technologies of residue use, is that of residue accumulation and economics. Unless the residues can be economically accumulated and transported to a point of use, the whole discussion makes little sense (Adams 1976). For nearly two decades this discussion has proceeded in the U.S. Much of the forest residue is still left in the forest because it is not economical to accumulate for processing, or there is no market available. In remote areas, in rough terrain, where transport is not sufficient, or where markets don't exist, it makes little sense to consider large scale residue recovery from the forest. In such cases, the highest use is as a soil amendment, or in local cottage industry. Technologies such as chunkwood chippers (Karsky 1989, Danielsson 1988) may make residue extraction more feasible.

In mills the problem is minimized and there is less economic deterrent to the accumulation and use of residues, than in the forest. However, if the mill is small there may not be enough material to economically make a product. The residue must then be accumulated over time and shipped to another location for use, if there is a market. This is often the reason for residue use as fuel rather than as a physical product. As with soil amendment for forest residue, the highest use for mill residue may be as fuel.

POTENTIAL PRODUCTS FROM RESIDUES

Energy

Though energy will not be discussed technically, it should be mentioned again. The use of mill residues for energy may be the highest use, through manufacture of charcoal, or direct burning to recover heat, steam or electricity. Energy recovery from wood is economical at all scales. It is an especially appropriate use where petro fuels are in short supply and the cost is very high. Socially, where domestic and municipal power is generated from wood waste, or in situations where firewood is the principal cooking and heating fuel, energy use for residues may far outweigh any product use.

Activated Carbon

Charcoal is often used as a cooking fuel in developing countries, but it can also have broader uses. One of these is as activated carbon, for filtration and clarification applications worldwide. There are about 50-75 manufacturers of activated charcoal throughout the world. Properties needed depend on particular uses such as for the sugar industry, air purification, and water purification. For water purification, different properties are needed for different contaminants.

Activated carbon is usually made by the carbonization and activation of wood or coal, but other materials of vegetable origin may also be used. Carbonization may be accomplished with devices ranging from the ubiquitous and historical earth kiln to more advanced masonry and steel kilns, and higher technologically advanced retorts and furnaces.

A carbon with a large adsorption capacity can be produced only by activating carbonized materials (Smisek, 1970). In one method, an activation agent (steam, carbon dioxide, etc.) reacts with the carbon. In another method, material is carbonized after the addition of substances such as zinc chloride which restrict the formation of tar. The latter method is commonly used with wood. The most widely used activation agents are zinc chloride, potassium sulphide, potassium thiocyanate, phosphoric acid, and sulphuric acid. Sometimes hydroxides of the alkali metals, magnesium chloride, and calcium chloride are used.

Chemical Extractives and Byproducts

Numerous chemical extractives are derived from woods. These include dyestuffs, resins, oils, naval stores, etc. Most of the time these products are from dedicated extractions using logged roundwood as the raw material. However, it may be feasible to use residues of selected species for extractive purposes.

Some of the extractive constituents of wood, although usually present in small proportions, sometimes have economic value. Their utilization can conceivably contribute to more effective reduction of forest and mill residues as part of complete residue utilization schemes.

Bark Extractives

Bark is generally richer in both quantity and complexity of extractives than the corresponding wood. If debarking is done at the mill site, accumulation of materials is expedited. Extractives of some barks can comprise 50% of total composition. A large number of organic chemicals are extractable from bark; carbohydrates, flavonoids, terpenoids, esters, steroids, complex phenols, etc. Combined crude chemical fractions, rather than pure compounds, are easier to prepare and have greater potential for larger volume markets. Crude fraction extractives with most promise are the tannins which are generally condensed polyphenols. Bark tannins from some species (ie. chestnut, wattle, quebracho) have proven useful for leather tanning. Their potential for capturing local markets for leather tanning depends on their availability in adequate quantities at low prices (Hergert 1989).

Tannins may also be potentially useful as adhesives in indigenous wood products industries. In these instances, bark tannins can partially replace resorcinol-formaldehyde adhesives. Tannins extracted from quebracho, for example, have a proven history as a component of phenolic resin in the plywood industry (Suomi 1983). Research has shown that spruce tannins can be used at levels up to 20% in phenolic resins without adversely affecting the quality of gluing (Liiri 1982). Research has also demonstrated that, under appropriate processing procedures, where phenolic resin is completely replaced with bark tannin extract, particleboards can be prepared to meet specifications of phenolic bonded boards. This research demonstrated that phenol and phenol-resorcinol modified resins can be replaced by bark tannins, providing an outlet for bark residues in particleboard and other forest products industries.

As a result of the world-wide energy crisis of the 1970's, efforts were made to replace synthetic adhesives with bark products. South Africa, Australia and Brazil have been most successful in this field. The only tannins in world trade currently being commercially used in wood adhesive application are those obtained from extraction of Acacia mearnsii bark (wattle tannin). In 1980 the provence of Natal, South Africa produced about 100,000 tons of wattle tannin, approximately 10% of which was used in adhesive applications (Pizzi 1983). While its usage is not large, wattle tannin can be economically used for wood adhesives, replacing high cost phenol and resorcinol. In developing nations, this can lead to less dependence of local wood industries on petroleum based adhesives.

Although condensed tannins from Acacia mearnsii (black wattle) have had commercial success in wood adhesives applications, attempts to use tannins from other sources, like conifer barks, have not been commercially successful (Porter and Hemingway 1989). Fundamental differences in the properties of wattle and conifer tannins account for this; differences in their reactivity, stability, purity, etc. Although there are several reported technical successes in wood adhesive applications using conifer tannins, no reports of their sustained commercial success exist (Hergert 1989). Additional research is needed to bring the potential of other bark tannins to the level of commercial acceptance that has been achieved by wattle bark adhesives.

Development of a bark tannin extraction operation utilizing forest residue requires significant capital expenditures for extraction equipment, and skilled personnel of technical competence. A feasibility study of the economic prospects for bark extracts has been prepared (Hemingway & Lloyd 1983 unpub.). One of the processes they considered involved the sulfite extraction of pine bark (350 tons/day dry bark equivalent) in conjunction with a large scale kraft pulping operation. They estimated a total capital investment of almost $\$12 \times 10^6$ (1983 prices) for the extraction process, including purchased equipment; refiner, extraction tanks, screw press, centrifuge, heat exchange tank, evaporator, spray drier and pelletized bagger. Although this study is not directed specifically to residue utilization, it provides initial guidelines concerning conversion operations, investment, labor requirements and operating costs.

Naval Stores

"Naval stores" is the traditional name given to products obtained from oleoresin of pine trees; rosin, turpentine, tar, pitch, pine oil and terpenes.

Naval stores are generally divided into three categories that indicate their source; gum naval stores, wood naval stores and sulfate (or tall oil) naval stores. Gum naval stores are those products obtained from the exudates of living trees by tree tapping operations. Wood naval stores are obtained from resin-loaded pine stumps long after the felling of the trees; the stumps are removed, chipped and the oleoresin products obtained by an extraction process. Sulfate naval stores (or tall-oil resins) are obtained as by-products of modern kraft pulping operations of softwood pines.

Naval stores production is only feasible in those regions of the world with natural or plantation pine forest resources. Suitable pine species for naval stores production are largely limited to Central America, China, Greece, India, North America, Pakistan, New Zealand, Soviet Union, and Western Europe (France, Italy, Portugal and Spain) (Stauffer, 1989). Not only do native pine forests have a limited distribution, but useful production of gum resin is further limited to those seasons in which the gum oleoresin can flow. Gum naval stores production is labor intensive, and no gum oleoresin treating plant has been constructed in recent years in the U.S. or western Europe.

Wood naval stores production might be appropriately considered a wood residue industry, since it involves utilization of otherwise unused stumps. Wood naval stores production process has been recently reviewed, and equipment needs and processing operations summarized (Gardner, 1989). Wood naval stores production is severely restricted to those few regions of the world with adequately large tracts of accessible old pine stumps. Stumps of immature trees (less than 10 - 25 years) typically contain uneconomically low levels of extractables. The only current producers of wood naval stores are the United States, Soviet Union and China. Earlier producers of wood naval stores included Mexico and Honduras, and, until 1980, Nicaragua. The Tropical Products Institute reported in 1982 that it was highly unlikely that any new wood rosin plants would be constructed (except perhaps in the USSR), partly because of the lack of suitable stumps, and partly because of the capital investment required (Greenhalgh, 1982). Such a plant would require the investment of over US$ 20 million to process 100,000 tons per annum of stump wood. With the naval stores production of China and the Soviet Union dedicated to internal consumption, the U.S. remains the only producer of wood naval stores for the world market. Changing political and economic conditions in Nicaragua may enable it to re-enter world trade in wood naval stores, presuming that its idle plant can be made operational again.

Hercules, Inc. has developed a process for increasing the oleoresin content of the stumps of newly felled trees (Fajans, 1980). In this root collar treatment, the herbicide Paraquat is injected near the base of the tree, and after two growing seasons the tree is harvested in the usual manner for pulp or timber, leaving the stump for harvesting and extraction. These stumps, made up of the portion from about 6 inches above the ground to about 18 inches below ground are harvested, extracted and processed as are old stumps in a wood naval stores plant. Such root collar treated stumps (even of immature trees) are reported to have commercially significant resin contents (Hays and Cottle, 1989). Although this process for making "old stumps out of new stumps" has shown some promise, there are serious environmental problems remaining and questions about its commercial potential. Commercial treatment seems practicable only if adopted on a large scale by a major pulp company that is

harvesting plantation pines and is already involved in sulfate naval stores production.

Development of wood naval stores is considered as unlikely considering the trend towards sulfate naval stores. But as mentioned above, sulfate naval stores are the by-products of kraft pulping of conifer trees, and are outside the scope of this report.

Animal Feed/Fodder

In many areas of the developing world, fodder derived from tree foliage is critical to the growing of cattle. The foliage can be a source of protein and vitamins. There may well be opportunities to also use wood residues, from some species, for producing fodder. Fodder can be made from wood by thermal and chemical processes that make the wood carbohydrate available to the digestive systems of ruminant animals. The processes needed are somewhat dependent on the wood species. For each species, the wood has to be treated and the digestibility determined by artificial rumen tests and then comfirmed by animal feeding trials to also determine efficacy of the treated wood and any animal health problems related to feeding the treated wood.

Composite Products

Some of the common uses of logging and mill residues around the world are for fiberboard, and particleboard furnish. It is logical to consider using wood residues for composite panel products in other countries where they are not now used. The discussion in this paper will be concerned with mineral/wood composite boards, fiberboards and particleboards.

Composite Board Processing

The terms fiberboard and particleboard apply to a category of sheet products that are part of a larger family of wood composition boards. Composition boards are distinct from solid wood in that they are composed of wood elements of varying sizes held together by an adhesive bond.

There are two basic steps in the manufacture of these products; the generation of elements or particles, and the recombination of these elements in sheet form.

Fiberboards use a furnish consisting of elements with dimensions of the same order of magnitude as those of the wood cells. In this discussion the term fiber applies to any element of that size and shape regardless of its origin. There are five different types fiberboard types, two are made by dry processes, and three are made by wet processes similar to paper. Wet processes require large quantities of water, up to 100 tons/ton of board produced (Anon. 1976).

Fiberboards are also classified by density. Insulation board (thickness, 3/8 to 3/4 in; density, 10 to 31 lb/cu.ft.) represents the lowest density class. It is made only by the wet process. Medium-density fiberboards (MDF) are made either wet or dry in a density range of about 40 to 50 lb/cu.ft. MDF-wet (thickness range 1/4 to 1/2 in) is generally used as siding material. MDF-dry (thickness, 3/8 to 1 in) competes with particleboard as core material for furniture. High-density fiberboard (density 55 to 70 lb/cu.ft.) is called

hardboard. There are significant differences between wet and dry formed hardboard, but they compete in the same market. Hardboard thickness ranges from 1/10 to 5/16 in. (Suchsland 1986).

Particle board is defined as any wood based panel product which is made from pieces of wood smaller than veneer sheets, but larger than wood fiber. In general the name particle board issued as a generic term for all particle panel products. The raw material for these products comes from a variety of sources including planer shavings, plywood mill waste, roundwood, sawdust, and pulp type chips. The residues of planing operations is the source material for a large segment of the market for uses such as flooring underlayment, furniture corestock, and molded items. Recently several types of particle boards termed flakeboards, have been used as sheathing or single layer floor panels. Depending on the particle or flake size and the panel construction flakeboards may be further classified as waferboard or oriented strand board (OSB). Particle boards are all dry formed, and range in density from 30 to 50 lb/cu.ft.

The density or unit weight of a wood species depends more on the number of fibers within a given unit of space rather than on the density of the individual cellulose fibers. As a result, the weight or density to panel property relationship of a fiberboard product is less dependent on the density of the original wood species than on the particleboard itself. In other words, it is difficult and impractical to make a particleboard with a specific gravity of 0.72 from species having 0.5 to 0.6 specific gravity. However, if heavy or dense woods are properly fiberized the resulting products will have excellent properties and moderate specific gravities.

A special type of fiber and particle boards that should be mentioned are the wood-mineral boards. These boards use inorganic binders such as portland cement or gypsum. The wood cement composites are strong, stiff, and resistant to moisture, fire, fungi, and insects. It is possible to produce a variety of structural and nonstructural products with the same basic manufacturing concept. In October of 1988, an international conference on Fiber and Particle Boards Bonded with Inorganic Binders was held at the University of Idaho. The proceedings of that conference are an excellent source of information on all aspects of this topic (Moslemi 1989).

Solid Wood Residue

With totally efficient logging and milling operations, very little recoverable solid wood residue should exist. In the interim, however, much solid wood material will be available. Some of this material will be large enough to put to use in the furniture and casegoods industry. Many of the parts for furniture and casegoods are relatively small and could be made from residues. The use of solid wood residues for boxes, crates, and pallets is also a good possibility, especially for longer pieces with wane. For small solid wood residue, the possibilities of use as raw material for toys, carvings, and art objects is possible. Another use for solid wood residue is blockboard panel manufacture. The potential for using edge and end gluing to make a wide variety of panel and moulding products is very good. Blockboard panels are most often used with veneer faces for cabinetry and paneling, while in the United States, glued-up standardized panels (Araman 1983) are being manufactured and sold at premium prices for do-it-youself customers or to

furniture and casegoods manufacturers. Araman (1979) has suggested standard-sized panels be made with tropical hardwoods.

AVAILABLE TECHNOLOGIES

In the following section we will discuss details of the technologies available for use of residues. These will be discussed, using a standard format, by processing disciplines, as follows.

Hardware (machinery needed)
Software (literature, manuals, standards and codes)
Skills (those needed for the process discussed)
Conversion operations (investment, labor requirements, operating costs).

Activated Carbon

Hardware: The manufacture of activated carbon is very proprietary in nature and operations are usually set up by the equipment producers. The basic steps of production involve crushers, grinders, extruders, driers, classifiers, and activators. The following list notes manufacturers of such equipment, of which we are aware:

Aeroglyde Corporation
Raleigh, North Carolina 27611
U.S.A.

Dervados Forestales SA
Po San Juan
Barcelona
Spain

Auson Ab
Barlastgatan 2
S-414 63 Goteborg
Sweden

Software: Smisek, M.; Cerny, S. 1970. Active Carbon, manufacture, properties and applications. Elsevier Publishing Company. 479p. Amsterdam, London, New York.

Skills: a wide mix of skills would be needed depending on the equipment being operated or the process being monitored.

Conversion operations:

Investment:
Labor requirements:

Chemical Extractives and Byproducts

Bark extraction: Development of a bark tannin extraction operation utilizing forest residue requires significant capital expenditures

for extraction equipment, and skilled personnel of technical competence. A feasibility study of the economic prospects for bark extracts has been prepared (Hemingway & Lloyd 1983 unpub.). One of the processes they considered involved the sulfite extraction of pine bark (350 tons/day dry bark equivalent) in conjunction with a large scale kraft pulping operation. They estimated a total capital investment of almost $\$12 \times 10^6$ (1983 prices) for the extraction process, including purchased equipment; refiner, extraction tanks, screw press, centrifuge, heat exchange tank, evaporator, spray drier and pelletized bagger. Although this study is not directed specifically to residue utilization, it provides initial guidelines concerning conversion operations, investment, labor requirements and operating costs.

Hardware: refiner, extraction tanks, screw press, centrifuge, heat exchange tank, evaporator, spray drier, and pelletized bagger.

Software:
Hemingway, R.W.; Conner, A.H., eds. Adhesives from renewable Resources. ACS Symposium Series 385. Washington, D.C. 1989. American Chemical Society. 510 p.

Hemingway, R.W.; Lloyd, R.C. 1983. Economic prospects for conifer bark extracts. USDA, Forest Service, Final Report; FS-SO-3201-47. Southern Forest Experiment Station, New Orleans, LA, USA.

Skills: Highly technical.

Conversion operations
- Investment: $US 13 million
- Labor requirements: Not known
- Operating costs: Not known

Naval Stores: The following reference is a definitive document on naval stores.

Zinkel, D.F.; Russell, J. 1989. Naval stores, production, chemistry, utilization. Pulp Chemicals Association, New York. 1060p.

Other Chemical Products: The diversity of this industry is so varied that the processes range from simple extractions with minimal equipment to multi-million dollar, and very technical operations.

Animal Feed/Fodder

The ruminant digestibiliy of the wood and bark of most species in only slightly digestible by ruminants but the wood and bark of Populus spp. is 30 to 50 percent digestible. Many schemes have been proposed to increase the digestibility and at this time only thermal treatments using steam are in use. The process consists of cooking wood chips for several minutes at 10 to 15 atmosphere pressure and then rapidly relieving the pressure. After this treatment the wood of most hardwood species is over 50 percent digestible by ruminants. The wood of softwood species does not respond as well to this

treatment. The most critical equipment in this process is the high-pressure-steam continuous digestor that is equipped with wood chip feeding valve. To produce steam treated wood for fodder, the following materials, information, and skills are needed.

Hardware:

- log handling equipment
- chipper
- conveyers
- special high pressure digester
- steam generator
- storage bins

Manufacturers of steam processing equipment include:

Stake Technology Inc.
208 Wyecroft Road.
Oakville, Ontario L6K 3T8
CANADA

Fritz Werner
Industrie-Ausrustungen GmbH
D-6222 Geisenheim
WEST GERMANY

Software:
Examples of the literature available include:

Anonymous. ND. Pro-Cell the alternative for the 80's. 15pp. Stake Technology Inc., 20 Enterprise Ave., Ottawa, Canada K2G 0A6.

Anonymous. ND. Analysing-planning-implementing: Steaming extraction process. 3pp. Fritz Werner, Industrie-Ausrustungen GmbH, D-6222 Geisenheim, West Germany.

Naumenko, Z.M.; Lainskaya, S.I. 1987. Production of fodder from cellulose-containing raw materials and estimating the efficiency of their utilization. Dhimiya Drevesiny No.3:3-9,120. Bryansk Technol. Inst., Bryansk, USSR.

Smith, J.E. 1980. Wood and bark wastes as feedstuff and fertilizers. In: Bewick, M.W.M. (Ed.) Handbook of organic waste conversion. New York, USA. Van Nostrand Reinhold Co. pp 209-226.

Utilization of Residual Forest Biomass. Pentti Hakkila. 1989. Springer-Verlag Berlin. p. 450-9.

"Wood and Wood-based Residues in Animal Feeds". Baker, A.J., M.A. Millett, and L.D. Satter. 1975. In: Cellulose Technology Research. A.F. Turbak, ed. ACS Symposium Series 10, p. 75-105.

Skills:
The process requires one operator per shift with knowledge of using high pressure steam.

Conversion operations:
Joint venture with product price at \$50-75 per ton
Two operators
Production: 40,000 tons per year

Composite Products

Hardware: The construction of a composite board plant is a large and complex project. The choice of primary and supporting equipment will vary with the product, plant capacity, and location. The costs of construction and operation will also depend on many variables. For detailed, current information on these subjects it would be advisable to go directly to a consultant or a manufacturer. A list of consultants is presented in Wood Based Panels International (1989).

Software: The following are some of the publications available on composite products:

Anon. 1987. Wood-based panels: Proceedings of the expert consultation. Food and Agriculture Organization of The United Nations, Rome Italy, 245p.

Anon. 1980. Wood-Based Panels in the 1980s. In: Proceedings of the symposium organized by the Timber Committee of the United Nations Economic Commission for Europe. Helsinki, Finland, May 1980. 271p.

Anon. 1978. Structural Flakeboard from Forest Residues. USDA, Forest Service, General Technical Report WO-5, Forest Service, Washington D.C. 241p.

Anon. 1976. Wet Process Fiberboard Plant, case study prepared for the FAO Portfolio of Small scale wood based panel plants. DEFIBRATOR FIBERBOARD AB, Stockholm Sweden. 30p.

Carll, C.G.; Dickerhoof, H.E.; Youngquist, J.A. 1982. U.S. Wood-Based Panel Industry:
Part 1 Production trends and changing markets. For. Prod. J. 32(6):14-23.
Part 2 Standards for panel products. For. Prod. J. 32(7):12-15.
Part 3 Research and technological innovations. For. Prod. J. 32(8):14-24.
Part 4 Energy environmental protection, and occupational safety and health For. Prod. J. 32(9):14-22.

Maloney, T.M. 1977. Modern particleboard and dry process fiberboard manufacturing. Miller Freeman Publications, Inc. San Francisco CA, USA. 672p.

Moslemi, A.A., Ed. Fiber and Particleboards Bonded With Inorganic Binders. Proceedings of International Conference on Fiber and Particleboards Bonded with Inorganic Binders. For. Prod. Res. Soc. Madison, WI, USA.

Moslemi, A.A. 1974. Particleboard , Vol. 1, Materials, Southern Illinois University Press. 244p.

Moslemi, A.A., 1974. Particleboard, Vol 2, Technology. Southern Illinois University Press. 245p.

Panel World Mag. 31(1): Jan. 1990. pp 60.

Suchsland, O.; Woodson, G. 1986. Fiberboard manufacturing practices in the United States. USDA, Forest Service. Agri. Hdbk. No. 640. 263p.

Vajda, Peter. 1975. A comparative evaluation of the economics of wood based panel industries. Food and Agriculture Organization of the United Nations, World Consultation of Wood Based Panels. New Delhi, India. Feb. 1975. 81p.

Skills: Modern competitive composite board plants are highly mechanized, computer controlled facilities, and relatively few employees are required to operate them. All skill levels are required, but the majority of the positions require training and an understanding of the equipment.

Conversion operations

Wet formed hardboard: (no new plants since 1971)
Investment: 4-31 Million $US.

Labor required: 102, 1/3 at each skill level, i.e. skilled, semiskilled, and unskilled.

Operating costs: 121-150 $US/ton

Dry formed hardboard
Investment: 26 Million $US

Labor required: ?

Operating costs: 130-155 $US/ton

Medium density fiberboard
Investment: 14-28 Million $US

Labor required: 72-141

Operating costs: 173-240 $US/ton

Particleboard
Investment: 13-22 Million $US

Labor required: 65-134

Operating costs:133-308 $US/ton

Waferboard
Investment: 12-60 Million $US

Labor required:100-160

Operating cost: N.A.

Strandboard (OSB)
Investment: 30-85 Million $US

Labor required: 26-250

Operating cost: 109-191 $US/thousand ft^2 (1/2 in. basis)

Solid Wood Residue

Drying Solid Wood Residue for Products

One of the keys to using solid wood residues is the drying of the material, especially if it is to be used for furniture or casegoods. Several different options are available, from the least sophisticated solar kilns or hot box driers to the most sophisticated steam, dehumidification, or vacuum kilns.

The major problem confronting the user relative to drying the residues is irregularity and small size of the pieces. Handling costs and physical considerations in the drying unit make the drying difficult at best. Small pieces also dry more quickly and are more subject to checking (cracking, splitting) and warping.

Solar kilns:

Hardware: Solar kilns can be relatively simple and easily built, thus avoiding manufacturers' costs, while still providing controllable drying conditions and even a modest degree of automatic operations. For lowest cost, they should be built using as much locally available building materials and components as possible. Supplemental energy from burning wood can be incorporated for night time and cloudy-day drying. A list of the most important materials and control items follows:

Major building materials:
- Concrete block
- Loose insulation
- Treated lumber and timbers
- Window glass or sheet plastic
- Sheet metal or treated plywood for duct-work and baffles
- Solar collector
  - Corrugated sheet metal and flat black paint
  - Charcoal
- Electical wire, switches, etc.

Control items
- Fans
- Blower (for external collector type)
- Motors
- Thermostats, humidistats, and relays if automatic control is used

Manufacturers of solar kilns:

Cambridge Glasshouse Company Limited
Comberton
Cambridge CB3 7BY
United Kingdom

Wood-Mizer Products, Inc.
Department CS8
8180 W. 10th Street
Indianapolis, IN 46214
United States

Software: The following are some of the current publications in solar drying:

Chen, P.Y.S. 1981. Design and test of a 500 board foot solar kiln. Forest Products Journal 31(3):33-38.

Chen, P.Y.S.; Helmer, W.A.; Rosen, H.N.; Barton, D.J. 1982. Experimental solar-dehumidified kiln for drying lumber. Forest Products Journal 32(9):35-41.

Gough, D.K. 1977. The design and operation of a solar timber kiln. Fiji timbers and their uses. Number 67.

Hall, G.S.; Hooks; R.A.; Plumridge,R.J. 1981. The art of timber drying with solar kilns. UNIDO Report ID/WG.338/1.

Harpole, G.B. 1988. Investment opportunity:The FPL low-cost solar dry kiln. USDA-Forest Service-Forest Products Laboratory-General Technical Report FPL-GTR-58.

Plumptre, R.A. 1973. Solar kilns: their suitability for developing countries. UNIDO Report ID/WG.151/4.

Plumptre, R.A. 1985. Solar drying kiln for sawnwood. Commonwealth Forestry Bureau, Forest Products Abstracts, Review Article. 8(2):33-45.

Prins, A.F. 1981. Oxford solar kiln research:1978-79. Commonwealth Forestry Review 60(3):187-196.

Read, W.R.; Choda, A.; Cooper, P.I. 1974. A solar timber kiln. Solar Energy 15:309-336.

Sharma, S.N.; Nath, P.; Bali, B.I. 1972. A solar timber seasoning kiln. Jour. of the Timber Development Assoc. of India 18(2):10-26.

Simpson, W.T.; Tschernitz, J.L. 1989. Performance of a solar/wood energy kiln in tropical latitudes. Forest Products Journal 39(1):23-30.

Steinmann, D.E.; Vermaas, H.F.; Forrer, J.B. 1980. Solar timber drying kilns: Part I: Review of previous systems and control measures and description of an automated solar kiln. Jour. of the Institute of Wood Science 8(6):254-257.

Steinmann, D.E.; Vermaas, H.F.; Forrer, J.B. 1981. Solar timber drying kilns: Part II: Microprocessor control of a solar kiln. Jour. of the Institute of Wood Science 9(1):27-31.

Tschernitz, J.L. 1986. Solar energy for wood drying using direct or indirect collection with supplemental heating: A computer analysis. USDA-Forest Service-Forest Products Laboratory Research Paper FPL-RP-477.

Tschernitz, J.L.; Simpson, W.T. 1977. Solar kilns: Feasibility of utilizing solar energy for drying lumber in developing countries. FPL-AID-PASA TA (AG) 02-75. US Forest Products Laboratory.

Tschernitz, J.L.; Simpson, W.T. 1985. FPL design for lumber dry kiln using solar/wood energy in tropical latitudes. USDA-Forest Service-Forest Products Laboratory General Technical Report FPL-44.

Wengert, E.M. 1980. Solar heated lumber dryer for the small business. Virginia Cooperative Extension Service, MT No. 20 C Utilization and Marketing.

Skills: Operators of solar kilns should know the basics of lumber drying, have an understanding of the function of a dry kiln and what it is expected to do, and have basic skills in electrical equipment. High-tech skills are not required.

Investment: This can be kept quite low with local building materials and simple control equipment.

Labor requirements: The operator should possess the skills listed above, supervise the loading and unloading of the kiln, and be available on a part-time basis to ensure the kiln is operating correctly and to check the progress of drying. Labor is required to load and unload the kiln.

Operating costs: Electricity for fans/blowers, labor, stickers, and maintenance are common costs. Insurance, taxes, land, and inventory costs may apply also.

Conventional Kiln Drying:

Hardware: Kiln drying of lumber or wood is usually done as a batch process in a chamber or compartment where heat is added and some control over temperature, humidity, and air circulation is exercised. In 'conventional' kiln drying, heat is supplied by steam circulating in coils, or by hot gases of combustion going directly into the chamber. Control of conditions in the chamber is important and can vary from personal monitoring and totally manual control of heat, humidity, and air circulation, to semi-automatic control by a recorder/controller, to sophisticated computer control, depending on needs and investment capital available. Common construction materials for the kiln include concrete block, brick, or prefabricated aluminum panels hung on steel or aluminum support members. Wooden structures are acceptable when temperatures are not expected to exceed about 130-140 F.

Control items:
Fans
Electric Motors (to power fans)
Some form of recorder/controller and appropriate sensors
Air compressor
Air motors (to control automatic venting)
Boiler (for steam kilns)
Steam Traps

Source of information on kiln manufacturers and kiln equipment:

World Wood. 1989. 1990 World Wood Buyer's Guide. World Wood 30(6):23-57.

Software: The following are some of the current operational manuals for lumber dry kilns.

Bachrich, J.L. 1980. Dry Kiln Handbook. Vancouver, BC: H.A. Simons (International) Ltd. 374p.

Boone, R.S., Kozlik, C.J., Bois, P.J., Wengert, E.M. 1988. Dry Kiln Schedules for Commercial Woods-Temperate and Tropical. Gen. Tech. Rep. FPL-GTR-57. Madison, WI. U.S. Dept. of Agric, Forest Service, Forest Products Laboratory, 158p.

Cech, M.Y., Phaff, F. 1977. Kiln Operator's Manual for Eastern Canada. Rep. OPX 192E. Ottawa, ON: Canadian Forestry Service, Eastern Forest Products Lab. 189p.

Hildebrand R. 1970. Kiln Drying of Sawn Timber. Nuertingen, Germany: Maschinenbau GmbH. 198p.

Mackay, J.F.G., Oliveria, L.C. 1989. Kiln Operator's Handbook for Western Canada. Special Pub. SP-31. Forintek Canada Corp. Vancouver, BC. 53 p.

McMillen, J.M., Wengert, E.M. 1978. Drying Eastern Hardwood Lumber. Agric. Handb. 528. Washington,DC: U.S. Dept. of Agric., Forest Service. 104p.

Pratt, G.H., 1986. Timber Drying Manual. London, UK: Princes Risborough Laboratory, Building Research Establishment. 122p.

Simpson, W.T., Ed. 1990. Dry Kiln Operator's Manual. Agric. Handb. 188. Washington, DC: U.S. Dept. of Agric., Forest Service.

Skills: Operators should know the basics of lumber drying, have an understanding of the function of a dry kiln and what it is expected to do. If boilers are used, some knowledge of boilers and steam in needed.

Investment: If boiler used, probably most expensive method of drying except vacuum drying. Kilns can be purchased as turn-key operations, or can construct own structure and purchase hardware and controls. When considering building own structure, best to contact hardware supplier beforehand and build to needs of equipment and product to be dried.

Labor requirements: The operator should possess the skills listed above, supervise the loading and unloading of the kiln, and be available on an as-needed basis to ensure the kiln is operating correctly and to check the progress of drying. Labor may be required to load and unload the kiln if fork lifts or track kilns are not used. Labor required to stack the lumber if mechanical stacking equipment not available.

Dehumidification Kiln Drying:

Hardware: Drying lumber in a dehumidification kiln is much like drying in steam heated or direct fired kilns in that the lumber is stacked in a chamber where there is control of temperature, humidity, and air circulation and is a batch process. The major difference is the method by which water is removed from the kiln air. The majority of the water is condensed on the coils of the dehumidifier and removed as liquid, rather than being vented to the outside atmosphere as is done in conventional steam or direct fired kilns. Dehumidification kilns are generally considered quite efficient in their use of energy. The energy contained in the warm moist air is not lost. When the moisture in the air condenses on the cold coils of the dehumidifier, the heat of vaporization is recovered. This recovered energy is reused in drying the lumber. Though they conserve energy, dehumdification systems operate on electrical energy and in some locations this form of energy may be expensive. As maximum temperatures are usually in the range of 120-160 F, the chamber may be constructed of plywood or prefab aluminum panels, but should be well insulated and have very good vapor barriers.

Control items:
- Fans
- Electric Motors (for circulating fans)
- Dehumidification Unit (included compressor, condensor & evaporator coils, and recorder/controller)

Source of dehumidification kiln manufacturers:

World Wood. 1989. 1990 World Wood Buyer's Guide. World Wood 30(6):23-57.

Software: The following are some of the current operational manuals or lumber dry kilns.

Simpson, W.T., Ed. 1990. Dry Kiln Operator's Manual. Agric. Handb. 188. Washington, DC: U.S. Dept. of Agric., Forest Service.

Mackay, J.F.G., Oliveria, L.C. 1989. Kiln Operator's Handbook for Western Canada. Special Pub. SP-31. Forintek Canada Corp. Vancouver, BC. 53 p.

Pratt, G.H., 1986. Timber Drying Manual. London, UK: Princes Risborough Laboratory, Building Research Establishment. 122p.

Boone, R.S., Kozlik, C.J., Bois, P.J., Wengert, E.M. 1988. Dry Kiln Schedules for Commercial Woods-Temperate and Tropical. Gen. Tech. Rep. FPL-GTR-57. Madison, WI. U.S. Dept. of Agric, Forest Service, Forest Products Laboratory, 158p.

Skills: Operators should know the basics of lumber drying, have an understanding of the function of a dry kiln and what it is expected to do. Knowledge of heating/air conditioning equipment (heat pump) is useful.

Investment: Purchase of commercial units usually recommended rather than 'putting something together' on your own, unless very knowledgeable about heating/air conditioning systems. Can build own chamber, but best to contact equipment supplier beforehand and build to needs of equipment and product to be dried.

Labor requirements: The operator should possess the skills listed above, supervise the loading and unloading of the kiln, and be available on an as-needed basis to ensure the kiln is operating correctly and to check the progress of drying. Labor may be required to load and unload the kiln if mechanized equipment is not available. Labor required to stack the lumber if mechanical stacking equipment is not available.

Vacuum kilns:

Hardware: The advantage of vacuum kilns is that they can reduce drying time dramatically without increasing the drying defects that normally occur when drying is accelerated at atmospheric pressure. They become more advantageous as lumber thickness and density increase. While they are not particularly complex, it is not likely that most forest products plants could build their own vacuum dryer. Vacuum kilns are generally cylinders or other metal structures reinforced to withstand the pressure differential. They also include

a vacuum pump for removing water. Vacuum kilns differ in how energy is delivered to the lumber, and can be categorized as follows:

Contact heating by either electically or steam heated platens. Both faces of every board are in contact with the energy source. This type of vacuum dryer would include a dehumidifier for condensing water for removal.

Dielectric heating. This is a technically complex and expensive energy source.

Alternate steam heating (atmospheric pressure) and drying (vacuum) cycles.

Controls are typically microprocessor based.

Manufacturers of vacuum kilns:

Maspell
Strada Ponte Romano, 1
17010 Rocchetta di Cairo
Savona, Italy

Wood-Mizer Products, Inc.
Dept. CS8
8180 W. 10th Street
Indianapolis, IN 46214
United States

Perifra
49, Rue D'Hauteville
75010 Paris, France

Hildebrand
Holztechnik Gmbh
Postfach 1860
D-7440 Nuertingen
Federal Republic of Germany

Software: The following are some references on vacuum drying:

Pagnozzi, E.G. 1980. Method for drying lumber. United States Patent No. 4,223,451. (basis for Maspell vacuum kiln, Italy)

Harris, R.A.; Taras, M.A.; Schroeder, J.G. 1984. Comparison of moisture content distribution, stress distribution, and shrinkage of red oak lumber dried by a radiofrequency/vacuum process and a conventional kiln. Forest Products Journal 34(1):44-54.

Trebula, P. 1984. Vacuum-drying hornbeam wood. Holztechnologie 1:20-22.

Simpson, W.T. 1987. Vacuum drying northern red oak. Forest Products Journal 37(1):35-38.

Ward, J.C.; Simpson, J.C 1987. Comparison of four methods for drying bacterially infected and normal thick red oak. Forest Products Journal 37(11/12):15-22.

Hamano, Y.; Nishio, S. 1988. Vacuum drying of wood with microwave heating. Mokuzai Gakkaishi 34(6):485-490.

Zhao, S. 1988. A new approach to eliminate checking in hardwood dried by a vacuum drying method. Holz als Roh-und Werkstoff 46(9):331-334.

Skills: Operators of vacuum kilns should know the basics of lumber drying, as well as the mechanics of vacuum systems. Since many of the vacuum kilns incorporate electronics and microprocessors, access to these skills is necessary to ensure operation.

Investment: Vacuum kilns using dielectric energy appear to be too costly in many applications, except perhaps for extremely high value species and products. Other types of vacuum kilns are less costly, but are generally considered economical only for slow and difficult to dry species.

Labor requirements: Skilled operator is necessary. Vacuum kiln requires more attention than conventional kilns because of short drying cycles.

Operating costs: May be high if electrical energy is required for the dielectric type or the type with platens heated by electrical resistance.

Edge- and End-Gluing Panels

Both logging and mill residues could be used to manufacture edge- and end-glued panels, and both lower and higher valued products can be made from these residues. Large branches and smaller or "residual logs", and slabs and edgings can provide furnish for glued products. Lower valued products would include block board panels and hidden structural furniture parts, while high value panels would include exterior furniture and cabinetry parts.

Hardware: Hardware needs are very broad, from sawmilling equipment to gluing clamps. Davis (1964) provides a general list of woodworking machines that would apply to residue utilization. His recommendations plus others are listed below. Sources for the purchase of such equipment are listed in different world trade publications, but are consolidated in Wood and Wood Products Red Book (Vance Publishing Corp. 1989), and 1990 Equipment Catalog and Buyer's Guide (Miller Freeman Publishing Corp. 1989).

* Small portable or fixed sawmills to process short and small diameter logs.
* Kilns (see section on drying)
* Cut-up saws
    Rip and crosscut
* Jointing and planing equipment to dress and prepare gluing surfaces.
* Finger jointers.
* Glue spreaders.
* Gluing clamps.
* Glue drying ovens.

Software: There are scores of publications on processing, covering all aspects of sawing, lumber cut-up, jointing, gluing, and planing. Sources of literature are:
* Sawing
    FAO Rome, Italy
    Sawlog breakdown and cutting patterns
        Machine alinement
        Machine performance
        Portable sawmilling: improve efficiency through training
        Sawmill improvement and modernization
        Sources of information
        Proceedings - workshops on sawmill productivity improvement
    Miller Freeman Publications Inc. San Francisco, CA, USA
        Sawmill Clinic Library-Modern sawmilling techniques
        Sawmill techniques for Southeast Asia
        Many other publications
    University of California, Forest Products Lab. Richmond, CA, USA.
        Wood Machining Seminar Proceedings 1967-1989
    United States Department of Agriculture, Forest Service
        Small sawmill operator's manual. Agric. Hndbk. No. 27. Forest Products Laboratory, Madison, WI, USA.
* Jointing/Planing (machining)
    United States Department of Agriculture, Forest Service
        Machining characteristics of United States woods. Technical Bulletin No. 1267. Forest Products Laboratory, Madison, WI, USA.
        Shaping and planing characteristics of plantation-grown mahogany and teak. Research Paper ITF-7. Institute of Tropical Forestry, Rio Piedras, PR, USA.
* Gluing
    United States Department of Agriculture, Forest Service
        Adhesive bonding of wood. Technical Bulletin No. 1512. Forest Products Laboratory, Madison, WI, USA.

Skills: Skill levels necessary are dependent on the level of the operation.
<u>Sawmill</u>: Sawmill operation with a small portable mill may require minimal training, but a high-speed electronically controlled sawmill will require a technical skill level.

Cut-up saws: Totally mechanical cut-up saws, either cross-cut or rip, require a minimum of operating skill but a greater amount of deductive reasoning to capture the highest yield possible from the lower grade residues. A higher skill level is necessary for electronically controlled cut-up saws and conversely less need for deductive reasoning to get the yield.
Planing: Planer operation does not require a high skill level.
Glue spreader: Minimal skill necessary.
Glue clamping: Minimal skill necessary.
Operating glue drying ovens: Minimal skill necessary.
Maintenance of equipment: A high level of skill is required to properly maintain any of the equipment for the jobs described above. Much of the waste in developing country mills, and marginal mills throughout the world, is due to poor maintenance of equipment.

Conversion operations: If the conversion begins in the forest, there must be harvest of the material from the tree tops and residual trees, extraction to the sawmill, and lumber production at the mill. Conversion beyond lumber production will include drying; cut-up of parts (rough mill operation); jointing of edges to be glued; glue spreading, clamping, and drying; and final planing.

Investment (all figures shown are FOB U.S., US$ X 10^3)

* Sawmill:	
Small portable circular sawmill	3 - 40
Small portable bandmill	4 - 40
Medium circular	10 -100+
Medium bandmill	15 -150+
* Cut-up saws:	
Cross-cut	0.5- 10
Ripsaw	1 - 10
* Jointer/Planer:	
Jointer (simple)	0.2- 2
Jointer (automated)	5 - 20
Planer (simple)	1 - 5
Planer (state of art)	15 -150
* Gluing:	
Glue spreader	1 - 5
Glue clamps (manual)	0.2- 1
Glue clamps (mechanical)	1 - 25
Glue drying ovens	5 - 40

Labor requirements: Depending on where the processing starts, the size, and sophistication of the operation, the labor requirements can vary extensively.

A small sawmill operation will generally require from 2 to 10 persons. A larger mill may require 10 to 20 persons. Minimal labor for a sawmill will include a sawyer and an offbearer. Further needs will include more offbearers, debarker operator, millwright, lumber stackers, truck drivers, etc.

Cut-up operations will require one operator for each cross-cut or rip saw. In a very small operation one person could operate

both machines on an alternating basis. In a larger operation either offbearers, roller cases, or conveyors are needed to move parts from one operation to the next. Also needed is a sawfiler to maintain the saws and machines.

Gluing operations will require a spreader or spreader operator, a clamp setter (whether manual or machine), and a drier operator. A maintenance person is needed for any mechanical operation.

Operating costs: The costs of operation is so dependent on the size of the venture, that it is difficult to state with surety. An operation based on sawmill residue might be done with a single saw, a jointer, hand gluing, and a planer, all operated by one or two persons. Such an operation might function for a few thousand US$ per year in a developing country. A sophisticated and integrated endeavor, from forest to final product, could be a multi million US-dollar per year venture. All scenarios in between are possible.

SUMMARY AND CONCLUSIONS

In this paper we have discussed the generation of logging and milling residues, the quantities estimated to exist, where reduction might occur, and how to use the residues that are generated.

The question might be asked, "Where are the opportunities in residue use?"

The best opportunities are in the reduction of residues, both in the forest and in the mills. Improved logging practices (including felling, skidding and bucking), altered diameter cutting limits for select species, use of lesser known species, and using more of the tree will all reduce what is left in the forest. In the mill, quality control in debarking, sawing, veneering and drying practices, better mill design, and better maintenance of equipment will reduce what is left in the mill.

From an industrial and an environmental view, the reduction of residues is necessary and the best decision. However, total reduction is not possible, and some recovery of residues is needed. In these cases residue use is necessary.

Depending on the type and location of the residue, various solutions are possible. If the location is remote, in rough terrain, where transportation is poor, or where markets are too far away, soil amendments and energy may be the best uses. But, if these are not barriers, then product options should be considered. Some of these options are:

Activated charcoal. A high value product, with a small but demanding market. The capital investment is fairly large, the product fairly specific as to application, and the market limited but growing.

Chemicals and Chemical Derivatives. Again, the product may be of substantial value. The technology is sophisticated and the capital investment generally high. High skill levels are generally necessary.

The product market is variable depending on the extractable substances, with considerable variance in value.

Animal Feed and Fodder. In areas where there is an abundance of wood residue and little other cattle feed, this product could be valuable. The process is technical and requires a fairly substantial capital investment, and as it is now, a royalty must be paid on the process as developed by certain manufacturers of the processing equipment.

Composite Products. Composites, whether all wood or wood and mineral products, have a good potential in all areas, providing funding for the needed facilities can be raised. The capital investment is great, and some level of technical ability is needed for mill operation.

Solid Wood Products. It is perhaps in this area that most of the initial activity will occur. Solid wood products can be produced readily in cottage industries, small cooperatives, and medium and larger industries. Less technology is required, in general, and capital requirements can be minimal.

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Anon. ND. The improve system. USDA, Forest Service, Forest Products Laboratory, Brochure. 2p. Madison, WI, USA.

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Craft, E.P. 1976. Utilizing hardwood logging residue: A case study in the Appalachians. USDA, Forest Service, Research Note, NE-230, 7pp. Northeastern Forest Experiment Station, Upper Darby, PA, USA.

Craft, E.P.; Emanuel, D.M. 1981. Yield of pallet cants and lumber from hardwood poletimber thinnings. USDA, Forest Service, Research Paper NE-482, 6pp. Princeton, WV, USA.

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TABLE 1
ESTIMATED WORLD WOOD RESIDUES (CUM X 1000)[1], 1987

Area [1]	Roundwood Production	Estimated Logging Residues [2]	Estimated Mill Residues [3]
Africa	419,131	778,386	272,435
Asian CPE	314,946	584,900	204,715
Latin America	378,360	702,668	245,934
Near East	54,458	101,136	35,398
Far East	642,913	1,193,981	417,893
Other Dv'ping	9,255	17,188	6,016
Developing Nations	1,819,062	3,378,259	1,182,391
Developed Nations	1,533,384	1,686,722	690,023
Total	3,352,446	5,064,981	1,872,414

[1] (FAO 1989).

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[1]Thousands of cubic meters.

[2]For the developing countries, an estimate of 65% of initial standing tree volume, based on a recovery of 50% (50% residue) of the standing volume of harvested trees and a 15% loss of volume in trees damaged during harvest.

For the developed countries, an estimate of 50% of the initial standing tree volume, based on a recovery of 55% (45% residue) of the standing volume of harvested trees and a 5% loss of volume in trees damaged during harvest.

[3]For the developing countries, 65% residues, based on an estimated 35% recovery from input volume, exclusive of shrinkage loss. This recovery level may be a bit high for much of the world.
For the developed countries, 45% residues, based on an estimated 55% recovery from input volume, exclusive of shrinkage loss (Anon. 1981).

APPENDIX

Partial List of Conventional Kiln Manufacturers.

American Wood Dryers, Inc.
15495 S.E. For-Mor Court
Clackamas, OR 97015
(503) 655-1955
FAX (503) 657-1304

Brunner-Hildebrand Lbr. Dry Kiln Co.
7523 Little Avenue, Suite 222
Charlotte, NC 28226
(704) 543-7121

The Coe Manufacturing Co.
Moore International, Memphis Div.
P.O. Box 16430
Memphis, TN 38186
(901) 345-5930

The Coe Manufacturing Co.
Moore International, Portland Div.
P.O. Box 23366
Portland, OR 97223
(503) 639-3121

Hildebrand
Holztechnik Gmbh
Postfach 1860
D-7440 Nuertingen
Federal Republic of Germany

Irvington-Moore
Div. of U.S. Natural Resources, Inc.
P.O. Box 40666
Jacksonville, FL 32203
(904) 354-2301

Irvington-Moore
Div. of U.S. Natural Resources, Inc.
P.O. Box 310
Woodland, WA 98674
(206) 225-8267
FAX (206) 225-8017

Kilntek
P.O. Box 5883
Asheville, NC 28813
(704) 254-6125

Lumber Systems, Inc.
P.O. Box 20849
Portland, OR 97220
(503) 256-2231

Southeastern Installations, Inc.
P.O. Drawer I
Lexington, NC 27293
(704) 352-7146

Wellons, Inc.
P.O. Box 381
Sherwood, OR 97140
(503) 625-6131

Partial List of Dehumidification Kiln Manufacturers

Brunner-Hildebrand Lumber Dry Kiln Co.
7523 Little Avenue, Suite 222
Charlotte, NC 28226
(704) 543-7121

Ebac Lumber Dryers
5789 Park Plaza Court
Indianapolis, IN 46220
(317) 577-7870

Hildebrand
Holztechnik Gmbh
Postfach 1860
D-7440 Nuertingen
Federal Republic of Germany

Irvington-Moore
Div. of U.S. Natural Resources, Inc.
P.O. Box 40666
Jacksonville, FL 32203
(904) 354-2301

Nyle Corporation
P.O. Box 1107
Bangor, ME 04401
(207) 942-8246

Southeastern Installation, Inc. (Uraken)
P.O. Drawer I
Lexington, NC 27293
(704) 352-7146